# Space Weather Technical Forecast

Issued on Tuesday, 21 December 2021 at 00:56 Local

**This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales**

**Space Weather Forecast Headline: Chance of G1/Minor Storms day 1 (21st). Chance of M-flares throughout. Chance of Active electron fluence developing later in the period. A possible Earth-directed CME later in the period - pending analysis.**

## Analysis of Space Weather Activity over past 24 hours

**Solar Activity:** Solar Activity has been Moderate over the past 24 hours, with a number of C-class X-ray flares observed, and one M1.9 flare at 20/1136 UTC. This has produced a coronal mass ejection (CME), and given its location near centre of the disc, there is the possibility of a glancing blow at Earth, pending further analysis. There are currently 8 sunspots on the visible disc, with newly numbered AR2913 emerging in the southeast quadrant, which appears to be simple and stable. The most prominent is a series of three regions in the southern central disc. AR2907 remains the most complex, which has started to grow again within its intermediate spots, with a penumbra evident either side of this region. This is now classified as a Dki/Beta-Gamma. AR2908 was the likely source for the M-class flare, but this continues to show some decay and is currently classified Cai/Beta. AR2909 also decayed, after a C4.1 flare at 20/0323 UTC, it is now classified Hsx/Alpha. All other regions are either small unipolar or bipolar regions, with limited flare risk, but situated within areas of plage, giving the potential for further development. No other CMEs were observed in available imagery.

**Solar Wind / Geomagnetic Activity:** Solar winds, as measured by the DSCOVR satellite at L1, started the period at background levels at 435km/s, rising to elevated and strong levels, with a peak of 638km/s at 20/2225 UTC as a result of a high speed stream from CH36. Density has generally been average or above average, with a peak of 27 ppcc at 20/2224 UTC, before decreasing back to below average. The Interplanetary Magnetic Field Strength (IMF), Bt started the period at moderate levels, with a peak of 15nT at 20/0000UTC, falling to moderate and weak, currently at around 5nT. The all important north-south component (Bz) ranged from -13nT to +7nT, with its southward (negative) peak at the start of the period. The phi angle was predominately negative throughout (towards the Sun). These parameters were the result of a strong CIR region arriving ahead of the transition into the fast wind of coronal hole 36 (CH36).Geomagnetic activity has been Quiet to Active (Kp 2-4).

**Energetic Particles / Solar Radiation:** The high energy proton flux (greater than 10 MeV) remained at Background levels. The high energy electron flux (greater than 2 MeV) was at mainly Background levels, but peaked at moderate during the diurnal maximum. The associated 24-hour integrated fluence remained well below the Active threshold and stable. A fluence of 1.77e6 was observed at 21/0000UTC.

## Four-Day Space Weather Forecast Summary

**Solar Activity:** Solar activity is expected to be predominantly Low, with further C-class flares and a chance (40%) of isolated M-class flares, mainly from AR2907, AR2908 and AR2909, but they cannot be ruled out from the other sunspot regions on the disc given further development. There are also a number of filaments visible in H-alpha imagery and whilst currently stable, they

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will need monitoring for any potential lift off.

**Solar Wind / Geomagnetic Activity:** A coronal mass ejection (CME) seen in SOHO/Lasco imagery at 20/1236UTC as a result of the aforementioned M-class flare from AR2908 (southern centre disc) gives the possibility of an Earth-directed CME, pending analysis. Elevated, possibly strong, solar winds are expected to persist through days 1 and 2 (21-22 Dec) due to CH36 and then CH35, before gradually easing on days 3 and 4 (23-24 Dec). Geomagnetic activity is forecast to be Quiet to Unsettled through days 1-2 (21-22 Dec), with Active intervals possible. These are most likely to occur early on day 1 (21 Dec) during the transition to CH35, when there is a chance of a G1 / Minor Storm. On days 3 and 4 (23-24 Dec), geomagnetic activity is likely to become mostly Quiet. However, this depends on the possible arrival of a Earth-directed CME (as mentioned above) which may give a glancing blow and enhance geomagnetic activity once again.

**Energetic Particles / Solar Radiation:** The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels and below the S1 level, although there is the potential for some increased flux from any flare activity. The high energy electron flux is forecast to be at background at first, but rising days 1-2 (21-22 Dec) due to recent solar wind enhancements from the arrival of the fast wind of CH36. Peak flux is likely to reach High levels (1000 pfu), but brief some drop outs are possible as any further enhancement from CH35 arrives. Persistently high flux is possible by days 3 and 4 (23-24 Dec). The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold, but there is the chance of rising above on day 1 (21 Dec). Whilst this risk increases through the period, it remains low confidence.

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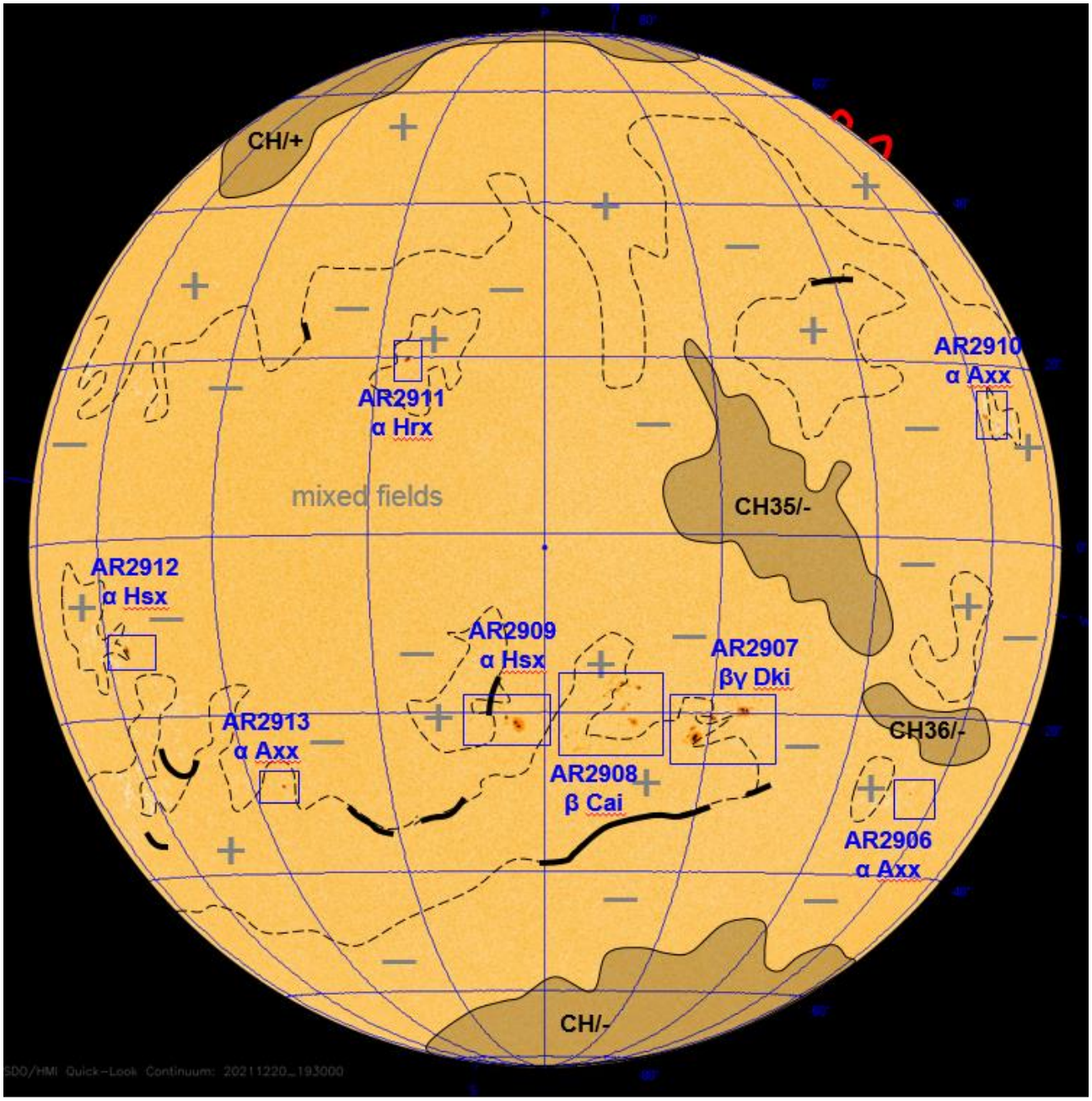
**Figure 1. Solar Analysis Valid 20/1930UTC.**




**Key:** Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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## Geomagnetic Storms:

Earth is connected to the fast wind of CH36, with solar winds currently elevated to strong, currently ranging between 600-640 km/s. Solar winds are likely to remain elevated through days 1-3 (21-22 Dec), with further enhancement coming from CH35. A gradual decline is then expected on day 3 (23 Dec) as coronal hole effects wane. This is supported by enlil and 27-day persistence which shows a fast wind enhancement until day 2 (22 Dec), and then easing.
Geomagnetic activity is forecast to be Quiet to Unsettled through days 1-2 (21-22 Dec), with Active intervals possible. These are most likely to occur early on day 1 (21st) during the transition to CH35, when there is a chance of a G1 / Minor Storm. On days 3 and 4 (23-24 Dec), geomagnetic activity is likely to become mostly Quiet. However, this depends on a possible Earth-directed CME, which left the Sun on the 20th Dec, which is pending analysis. If this was to give a glancing blow at Earth later in the period, there is the chance of geomagnetic activity becoming enhanced once again.

| Geo-Magnetic Storm Probability (Exceedance) | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| Minor or Moderate | G1 to G2 | No | 30 | 10 | 20 | 20 |
| Strong | G3 | No | 1 | 1 | 1 | 1 |
| Severe | G4 | No | 1 | 1 | 1 | 1 |
| Extreme | G5 | No | 1 | 1 | 1 | 1 |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

Pending analysis of a CME, which leff the Sun on the 20th Dec, which has the possibility to be Earth-directed.

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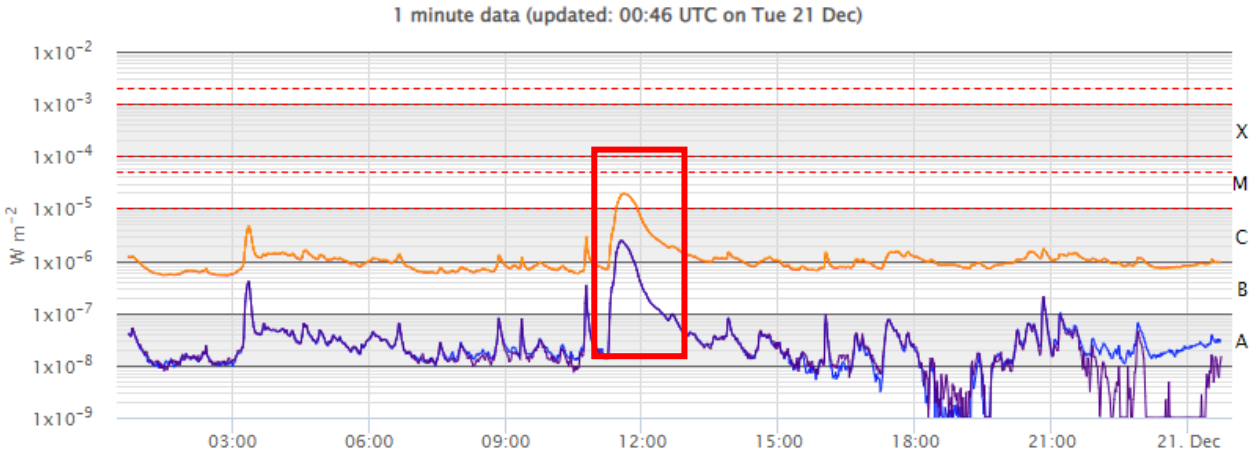
**Radio Blackouts - X-Ray Flares:**

There are currently eight active sunspot regions on the Earth-facing disc, however most of these are small and simple. The exception to this are three regions close to centre disc in the southern hemisphere, with AR2908 producing an M1.9 flare at 20/1136 UTC, AR2909 a C4.1 flare at 20/0323 UTC. Despite this, all these regions have shown some form of decay over the past 24 hours. AR2911 in the northeast, was the source of an M-flare on the 17th, but has simplified to become a unipolar region.

With all regions either small, or showing signs of decrease, solar activity is forecast to be predominantly Low, with further daily C-flares expected. There is a chance (30-40%) of isolated M-class flares throughout the forecast.

| X Ray Flares | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability | | | (%) | (%) | (%) | (%) |
| Active | R1-R2 M Class | Yes | 40 | 40 | 40 | 40 |
| Very Active | R3 to R5 X Class | No | 2 | 2 | 2 | 2 |

**Figure 2: GOES-16 X-Ray Flares – shows the M-class flare (red square) which has produced a CME, which could be Earth-directed – pending analysis.**

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**Solar Radiation Storms - (High Energy Protons):**

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at Background levels.

Despite the large number of sunspots on the disc, a number of which are now moving into an improved geoeffective location for radiation storms, their small size and generally simple magnetic structure means that proton rich flaring is unlikely. Background levels are expected to persist, with a chance of some small increases from any notable flares that do occur. However, there is only a very slightly above background risk of rising to the S1 alert level.

| Radiation Storms Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $s^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ S1** | No | 5 | 5 | 5 | 5 |
| **Very Active** | **≥ S3 *** | No | 1 | 1 | 1 | 1 |
| * S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$) | | | | | | |

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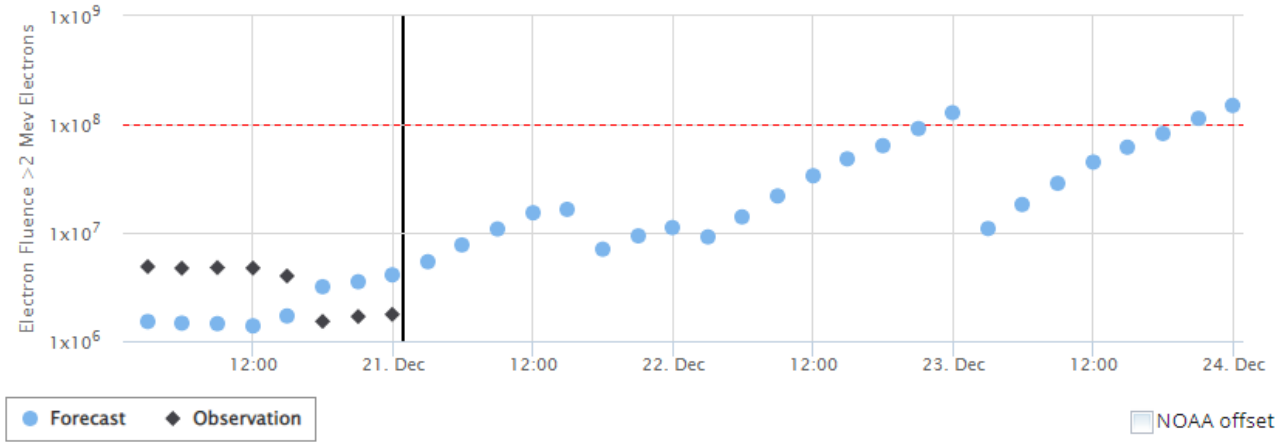
**High Energy Electrons Event (≥ 2MeV):**

The high energy (greater than 2 MeV) electron flux as observed by GOES-16 is currently at moderate levels. Once early geomagnetic activity on day 1 (21 Dec) ease a gradual build of observed flux is likely, peaking at High levels (above 1000 pfu). Further enhancement from any arrival of fast wind from CH35 on day 1 and 2 (21-22 Dec) could bring dropouts to the observed flux, before Moderate to High levels are expected to resume. This enhancement is currently uncertain however, giving low confidence to the forecast by days 3 and 4 (23-24 Dec), which depends on the arrival of a CME.

The associated 24 hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold until day 1 (21st) with a chance of rising above. Whilst this risk increases through the period, it remains low confidence due to uncertainty around the strength of any enhancement from CH35 and a possible CME arrival late in the period - pending analysis. REFM is giving good guidance showing a rising trend for the current solar wind enhancement.

| GEO Electron Environment<br>Probability (Exceedance) | Level ($cm^{-2}$ $sr^{-1}$ $day^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC)<br>(%) | Day 2 (00-24 UTC)<br>(%) | Day 3 (00-24 UTC)<br>(%) | Day 4 (00-24 UTC)<br>(%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ 2 MeV ≥ $1x10^8$** | No | 30 | 30 | 40 | 40 |
| **Very Active** | **≥ 2 MeV ≥ $1x10^9$** | No | 1 | 1 | 1 | 1 |

**Figure 3: Observed electron fluence from GOES-16 and REFM forecast data.**

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